

S-6/PHSH/CC-14/24

TDP (Honours) 6th Semester Exam., 2024

PHYSICS

(Honours)

FOURTEENTH PAPER : CC – 14

Full Marks : 60

Time : 3 Hours

*Answer from **both** the Groups as directed.*

The figures in the margin indicate full marks.

*Candidates are required to give their answers
in their own words as far as practicable.*

GROUP—A

1. Answer any **six** of the following questions :

2×6=12

- (a) Explain why black-body radiation is white.
- (b) Identify the difference between the basic assumption of Planck theory and classical theory related to black-body radiation.
- (c) Why Gibbs Paradox is called a paradox?
- (d) Write the significance of partition function.
- (e) What do you mean by Bose-Einstein condensation?

(2)

- (f) Why liquid helium does not have any triple point?
- (g) Explain the concept of an electron gas in a metal.
- (h) Fermi-Dirac gas possesses appreciable energy at absolute zero. Explain how it is possible.

GROUP—B

There are *four* questions from Question No. **2** to Question No. **5**. Answer either (a) **or** (b) from each question given below : 12×4=48

- 2.** (a) (i) Write down Stefan-Boltzmann law of radiation and derive it from Planck's law.
- (ii) Show that Planck's law reduces to Wien's law for shorter wavelength and Rayleigh-Jeans law for longer wavelength.
- (iii) A metallic ball of surface area $2 \times 10^{-2} \text{ m}^2$ and at a temperature 327°C is placed in an enclosure at 27°C . If the surface emissivity of the metal is 0.4, calculate the time rate at which heat is lost by the ball ($\sigma = 1.37 \times 10^{-11} \text{ kcal sec}^{-1} \text{ m}^{-2} \text{ K}^{-4}$). (2+3)+(2+2)+3

(3)
(OR)

- (b) (i) State briefly how can you experimentally measure the energy distribution of black-body radiation. Discuss the nature of energy distribution in the spectrum.
- (ii) Why does a black-body radiator in the form of a hollow enclosure have its inside surface coated black in practice though it is not necessary according to Kirchhoff's law?
- (iii) An aluminium foil of relative emittance 0.1 is placed between two concentric spheres (assumed perfectly black radiators) at temperatures 300 K and 200 K respectively. Find the temperature of the foil after the steady state is reached and the rate of energy transfer between one of the spheres and the foil ($\sigma = 5.672 \times 10^{-8}$ SI unit).

(3+2)+3+4

3. (a) (i) State the equipartition theorem and applying it determine the molar specific heat of monatomic, diatomic and triatomic gases.
- (ii) Derive an expression for the average thermal speed of a particle of mass m in an ideal Boltzmann gas at a temperature T . What is the value of this speed for an electron system obeying MB statistics at 300 K?

(4)

- (iii) Consider a system of 8 non-interacting distinguishable particles distributed over two nondegenerate energy states $+E$ and $-E$. What is the maximum entropy of the system? Find also the corresponding total energy of the distribution. 4+4+4

(OR)

- (b) (i) Set the relation between entropy and partition function for the essembly of ideal gas molecules.

- (ii) A system consists of three spin $\frac{1}{2}$ particles, fixed in space and placed in an external magnetic field $\vec{B}$. Each particle has a magnetic moment μ which can be either parallel or antiparallel to $\vec{B}$. Find the number of microstates and macrostates of the system.

- (iii) The partition function $Z(V, T)$, for some physical system is given as :

$$Z(V, T) = \exp [(8\pi^5 k^3 V T^3)/(45 h^3 c^3)]$$

where the symbols have their usual meanings. Calculate the internal energy for such system. 4+4+4

(5)

4. (a) (i) An ideal Bose-Einstein gas consists of particles with an internal degree of freedom. Besides the ground state $\epsilon_0 = 0$, suppose just one excited level is ϵ_1 important. Find the condensation temperature of this gas.
- (ii) Derive the BE distribution formula.
- (iii) Explain why dilute gases obey classical statistics while dense systems follow quantum statistics. 5+4+3

(OR)

- (b) (i) Consider gas enclosed in a volume V and in equilibrium at temperature T . The photon is massless particle. Show that total number of photons in the volume is proportional to T^3 .
- (ii) Compare the Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac distribution functions. Under what conditions, do Bose-Einstein and Fermi-Dirac yield the classical statistics?
- (iii) Explain about the critical temperature and its significance in a Bose gas. 3+(3+2)+(2+2)

5. (a) (i) Explain physically why would you expect a lower value of the electronic specific heat in metals when FD statistics is used instead of MB statistics.

(6)

- (ii) If f is the FD distribution function, show that

$$(a) \quad \frac{\partial f}{\partial E} = -\frac{f(1-f)}{k_B T} \text{ and}$$

$$(b) \quad \int_{-\infty}^{\infty} -\left(\frac{\partial f}{\partial E}\right) dE = 1$$

- (iii) Calculate the Fermi energy at 0 K of sodium containing one free electron per atom. The density and the atomic weight of sodium is $9.7 \times 10^2 \text{ kg/m}^3$ and 23 respectively. Also find the Fermi temperature. 3+(3+3)+3

(OR)

- (b) (i) Show that the Fermi level corresponds to the energy level for which the probability of occupation is $\frac{1}{2}$.
- (ii) Derive the expression for the density of states for a three-dimensional electron gas in a metal.
- (iii) How does the electrical conductivity of a metal change with temperature? Explain using the concept of electron gas. 3+4+(2+3)

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